

Opinion on dissertation by
Marta Kerkhoff, MSc.

„Tracing Microendolithic Ichnocenoses: a paleoecological and taphonomic approach over the Phanerozoic “.

The dissertation by Marta Kerkhoff, MSc. is focused on the interaction of microorganisms with their substrate. To solve this topic, the author chose to study microbial activity in different marine environments, paleoecological conditions and in sediments of different ages. Beside of traces of the activity of microendolithic organisms on foraminifera shells, manifestations of colonization of hardgrounds, microbial coating formation, mineralization of skeletons, dysoxic infauna and epifauna, biodegradation of fossil remains, authigenesis of framboidal pyrite, and other diagenetic phenomena on organism shells and in carbonates were also studied. The results are summarized in the thesis and in three articles published in Elsevier journals (Marine Micropaleontology, Paleoworld and Cretaceous Research).

a) Current topic of dissertation

Marta Kerkhoff applies a modern approach of micropaleontological research with a specific focus on bioerosion. If handled well, such thesis has the potential for obtaining original knowledge, which also provides a possibility for high-quality publication. The author fully utilized of interesting topic of the dissertation to obtain an interesting results and their publication.

b) Processing methods

To solve the problem of bioerosion, a multidisciplinary approach has been chosen to study a morphology of traces of microendolithic organisms, making their resin casts, ultrasonic cleaning, SEM visualization of traces, X-ray tomography, analysis of biofilms by using EDAX, Raman spectrometry, up to analytical methods of measuring sulfur isotopes. The microboring traces has been studied on approx. 300 samples of benthic foraminifera from Late Oligocene and Miocene sediments of the Western Carpathians (5 locations), completed by study of bioerosion on substrates and foraminifers from Paleozoic carbonates of the Prague Basin (792 thin-sections, 100 tests), and those on the molluscs and belemnites from the Maastrichtian sediments of the Rügen area in northern Germany (White Chalk of boreal sea), as well.

c) Results of the dissertation

The results of the dissertation are presented in the thesis and in the published papers.

The doctoral thesis comes from an extensive theoretical base of microbial erosion, from the historical review of the research of microboring and coating-forming organisms (cyanobacteria, algae, filamentous microbes, and various other producers), their traces and morphotypes, taxonomic and ethological classification (*Dominichnia*, *Praedichnia*, *Saccomorpha*, *Rhopalia*, etc.), strategy and taphonomy of endoliths, paleobathymetry of ichnofauna according to photic zonation, etc. The theoretical part is complemented by an overview of microbial activity in various marine environments of the Mediterranean region, Northern Sea, Azores, reef areas of Central America and Middle East, as well as from various Early Paleozoic, Mesozoic and Cenozoic sediments.

The results obtained from the study of bioerosion on the tests of benthic foraminifera and carbonate substrates in the Oligocene and Miocene sediments of the central Paratethys were published by Kerkhoff, M. et al. 2023: Marine Micropaleontology. According to this paper, microbial activity in Paratethyan environments was enhanced mainly by quasi-anoxic conditions, which are manifested by the absence of microendoliths of the photic zone, but also by the dominance of dysoxic foraminifera species, the activity of chemotrophic bacteria and the formation of framboidal pyrite, the contents of sulfur (with negative isotopes), phosphorus and iron, etc.

The author of the dissertation contributed to achieve an interesting knowledge about microboring organisms in the Paleozoic sediments of the Prague Basin (Kerkhoff, M. in Holcová, K., et al. 2023, Palaeoworld). Based on the study of bioerosion, an increase of the traces of bacterial and fungal activity was recorded from the Ordovician to the Lower Devonian. This development of the microendolithic ecosystems of the Prague Basin reflects the trend of climatic cooling and a decrease in nutrient availability. A significant increase in the activity of phototrophic microborings in the Middle Devonian (Emsian) reflects a better oxygenated environment, oligotrophic conditions and the shift of the Prague Basin from a temperate to a tropical climate zone.

Other results of the dissertation became a part of the paper submitted to the Cretaceous Research journal (Kerkhoff & Holcová, in print). The publication analyzes the traces of microendolithic algae and fungi on the tests of benthic foraminifera from the Upper Cretaceous sediments of the boreal region. The author identified ichnotaxa of microendolithic organisms (e.g. *Ichnorecitulina*, *Rophalia*, etc.), and also described their new species *Saccomorpha cordiformis*. Based on the facility of these traces to chlorophytic and rhodophytic algae and heterotrophic sponges, the author interpreted the conditions of their bioerosion and sedimentation in the deeper photic to dysphotic zone.

d) Review questions and comments

1. The conditions of photic zone were also determined based on microboring traces of fungi, which, as heterotrophic organisms, do not reflect the light conditions of the environment (Óloris, 2004). Is it therefore correct way to derive the photic conditions of the environment from presence of fungi?
2. The intensity of bioerosion also depends on shell mineralogy of foraminifera, while shells with a higher concentration of Mg are bored and dissolved more intensively than low-Mg tests (e.g. Cherchi et al. 2012). The question is whether such differences were not observed in the intensity of bioerosion between porcelaneous foraminifera (e.g. *Quinqueloculina*, *Spirosigmilina*) and hyaline foraminifera (e.g. *Nonion*) and in foraminiferal microfauna the Paratethys? The rate of bioerosion on the tests of porcelaneous foraminifera also increases in environments with lower pH and acidification. Similarly, increased contents of heavy metals (e.g. Fe, Al, P, Cu, etc.) support the activity of microborings (e.g. microbes, bacteria, fungi, etc.). Did not result similar implications from the EDX and Raman spectrometry analyzes presented in the work of Kerkhoff et al. (2023)?
3. The study of taphocenoses proves a mixing epiphytic foraminifer unaffected by bioerosion with infaunal tests affected by microbes (Kerkhoff, submitted). This mixing is explained by bioturbation. The question is whether these sediments are reworked by some trace fossils? With absence of bioturbation such mixing could also resulted from taphonomic filtering or different conditions at the bottom-sediment interface.
4. In the paper by Kerkhoff et. al. (2023), the author described fungal hyphae of *Saccomorpha* sp. on the tests of large foraminifera *Amphistegina*. This co-occurrence seems as abnormal, because of *Saccomorpha* belongs to the microendoliths of the aphotic zone, while *Amphistegina* hosts symbiotic algae dependant on the light availability and photosynthesis. What could be the explanation of this incompatibility? Is this a secondary occurrence of *Amphistegina* tests transported to the aphotic zone from euphotic zone of the shelf?
5. The intensity of microbial activity in carbonate sediments certainly depends on the condensation. According to the sequence stratigraphy, the condensation rate increases during the transgression and culminates during the maximum flooding surface. From the study of microendoliths in the limestones of Barrandien, a trend of increasing abundance of endolithic organisms from the Ordovician to the Middle Devonian was found. Could this trend of increasing microbial activity also be correlated with the condensed sections of the Barrandien limestone formations?

6. Traces of microborings on the skeletons of echinoderms and shells of other organisms from the Devonian limestones of the Prague Basin are very similar to the traces on crinoidal ossicles, coralline algae and other skeletons from Mesozoic limestones described from the Western Carpathians by Mišík et al. 2006 (Slovak Geol. Mag), Mišík & Reháková 2009 (Limestones of Slovakia, VEDA SAS), etc. These studies of microborings could have been mentioned in the dissertation dealing with microbial activity.

7. The conical holes after boring of nauid gastropods belong to the ichnotaxon *Oichnus* (Bromley 1981), and not to *Ooichnus*, as is quoted in the paper by Kerkhoff et al. (2023, p. 13).

e) Final statement

Doctoral thesis by Marta Kerkhoff, MSc. consists of published papers and from comprehensive review of microbial activity in the dissertation (pp. 1 – 57). The published parts of the thesis were subjected to peer review process in scientific journals with a high ranking of Impact factors and Quartiles (Marine Micropaleontology, Paleoworld, Cretaceous Research), which in itself confirms their international quality. The activity mentioned PhD. student is also documented by participation of Marta Kerkhoff at numerous international micropaleontological conferences (e.g. TMS Anniversary conferences 2020, 2021, FORAMS Perugia 2023, etc.). Therefore, as a reviewer, I evaluate the submitted thesis positively, and based on successful defense of dissertation, I propose to award Marta Kerkhoff, MSc. by academic degree PhD - philosophiae doctor).

In Banská Bystrica on March 12, 2024


Ass. Prof. RNDr. Ján Soták, DrSc.